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To Touch or Not to Touch: Evaluating Student Laboratory Outcomes of Hands-On versus Visual Examination of Prosected Cadavers

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Abstract: We utilized the physical manipulation of cadaveric donors by students to evaluate learning outcomes in two undergraduate anatomy courses. Students (n = 176) were assigned as those whom 'manipulated' (n = 100) or 'did not manipulate' (n = 76) donors, and data were compared to performance on laboratory assessments. A Fisher's exact test was conducted within individual and combined course populations to assess if the relationship between physical touch and receiving a passing grade is more than expected by chance. BIO 201 'manipulating' students received a 'C' or better (n = 58) vs. 6 D, F, or Withdraw grades (DFW) on lab practicals as compared to those who did not manipulate (n = 33 DFW vs. 18 C or better) ($p < 0.0001$). BIO 221 'manipulating' students (n = 34) received a 'C' or better vs. DFW grades (n = 2), while 'non-manipulating' students were able to earn outcomes of 'C' or better (n = 13 vs. 12 DFW). However, students involved in donor manipulation were more likely to receive a 'C or better' (p = 0.0002). Analysis of the data as a single cohort indicates non-manipulating students are 7.24 times more likely to earn a 'DFW' on lab practicals, demonstrating that students are better prepared for laboratory assessments when encouraged to manipulate anatomical structures.

Keywords: cadaveric manipulations; prosection; undergraduate anatomy

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1. Introduction

Human anatomy and the combined human anatomy and physiology courses are historically difficult for students, as these courses require extensive mastery of anatomical language to be successful, which also involves significant time investment on part of the student [1,2]. Performance in anatomy or anatomy and physiology courses is of great concern due to the large number of courses offered at undergraduate institutions across the country. Unfortunately, student success in these disciplines is not guaranteed and can vary due to their academic background, previous course experience, socioeconomic background, and college-preparedness [3].

Anatomy courses typically include a range of delivery formats including traditional didactic lecture, mixed, synchronous lecture and laboratory format, hybrid courses with an asynchronous, remote component, and completely online delivery modalities [4–6]. Additionally, these delivery mechanisms are further complicated by the range of laboratory formats and specimens that may be used for learning various anatomical structures. Indeed, plastic models, digital anatomical software programs, dissections of fetal pig, feline, bovine and/or sheep specimens are frequently utilized to progress through the anatomical structures relevant to a specific course. Anatomical specimens are typically included to best fit the course content and/or organization, as well as specimen availability and cost. Finally, cadaveric donors are considered the gold-standard of anatomy education, as working with

donors provides a deeper understanding of human structures [7–10]. While donors are used in programs at the preprofessional level, their inclusion is more limited typically due to the costs associated with cadaver specimens and body donation programs.

At our previous institution, Missouri Southern State University, BIO 201, Human Anatomy (HA), is a 200-level (sophomore) course that begins with the cell and anatomical terms, and uses a systems-based approach (including embryology) to teach anatomical knowledge. It is an elective for pre-professional (pre-medical, dental, pharmacy, physician assistant, physical therapy) students. By comparison, the BIO 221, Human Anatomy and Physiology II (APII) course, is second in a two-course Anatomy sequence, required for Health Science (pre-nursing, pre-dental hygiene, pre-radiologic technology) students before matriculating into their respective programs. Collectively, the courses are rigorous, have high content volume, and are extremely demanding upon students. Indeed, these courses historically have a high 'DFW' rate, or high number of non-passing grades (D, F) and withdrawals (W). As such, the courses provide an opportunity to examine opportunities to improve student outcomes and reduce repeat enrollment.

The HA and APII courses at Missouri Southern initially utilized models, anatomical software, feline specimens and dissection to progress through the required anatomical structures. However, cadaveric donors were incorporated to provide content immediately relevant to human structures beyond models and/or digital anatomical resources. Students completing the first course iteration expressed excitement for the unique learning opportunity the donors provided, but were initially hesitant to physically work with and manipulate the tissues, similar to reports noting the stress and apprehension related to the emotional experience of donor dissection [7–14]. Although many students overcame their reservations as the semester progressed, and performed exceedingly well on the identification-based laboratory assessments, others failed to acclimatize to working with human bodies, and performed far worse on the practical assessments compared to their peers. From this observation, we hypothesized that physical manipulation of donor specimens would positively impact laboratory practical performance in the Human Anatomy and Human Anatomy and Physiology courses.

Here, we report a longitudinal study of student outcomes in an undergraduate anatomy course and how physical manipulation of donor specimens results in improved laboratory practical performance.

2. Materials and Methods

2.1. Course Logistics

BIO 201 and BIO 221 are five-credit-hour courses with three, one-hour lectures and two, two-hour laboratories per week. In a single, 16-week semester with 32 lab sessions, each course had a total of 48 lecture and 64 laboratory contact hours each. Both courses had a maximum enrollment of 24 students. Prosections (n = 3) were shared among the courses each semester and were completed by upperclassmen under the guidance of a faculty member (did not include the authors). The same instructor for each course was also the faculty member leading the laboratory sessions. Course grades represent a combined lecture exams and laboratory practicals, following a 90, 80, 70, 60, and below grading scale. Course grades were assigned as follows: A, 100–90%; B, 89–80%; C, 79–70%; D, 69–60%; F, 59% and below. Awarded grades of D or F are non-passing grades, and would prevent students from using these courses as a successful prerequisite(s) for subsequent anatomy courses. For study purposes, only laboratory outcomes were evaluated as the two courses have different content covered for lecture material, and the evaluation of physical manipulation of the donors was restricted to laboratory sessions.

2.2. Practical Examinations

Practical assessments (n = 4) consisted of 50 first-order, identification-based questions. Structures tagged for examination were selected from a master list which was provided to the students at the beginning of each system; the laboratory structure lists were consistent

year to year, and semester to semester. Prosected donor specimens (n = 3) were the primary focus of the practical examinations; however, anatomical models, and/or animal specimens were occasionally utilized if they better represented the question tag due to accessibility, i.e.,) bovine eye. The structures included in each examination were identical across multiple sections of the same course, but varied slightly from semester to semester. The students were given 40 min to complete all questions.

2.3. Identification of Manipulating and Non-Manipulating Students

Students were enrolled in BIO 201 or 221 in seven semesters spanning the academic years 2011–2012, 2012–2013, 2013–2014, 2014–2015 and 2015–2016. Each lab session included a faculty-led review as well as peer-led teaching and identification of structures. Students did not have access to the donor specimens during didactic lectures nor outside of scheduled lab hours. The number of times a student made physical contact with the prosections was logged by the teaching faculty over the course of the semester, throughout all lab sessions, until it reached ten times. At this point, it was concluded a student was comfortable working with the donors and were no longer evaluated for counting purposes. For all remaining students, they continued to be evaluated over the entirety of the semester. The authors elected to categorize the students as 'manipulators', if they elected to physically manipulate the prosected specimens at least five times or greater during the laboratory sessions over the course of the 16-week semester. Any student that failed to physically manipulate a prosected specimens five or more times throughout the entirety of the course was included as 'non-manipulating'.

2.4. Statistical Analysis

A Fisher's exact test was conducted within individual courses and among a combined course population to assess whether the relationship between physically manipulating a donor and receiving a passing grade on lab practical assessments is more than expected by chance. This statistical analysis was conducted using the GraphPad Prism 7 software program (San Diego, CA, USA) with a p value set at less than 0.05.

3. Results

The data for students enrolled in BIO 201 and BIO 221 were collected and analyzed using a Fisher's exact test. For statistical analysis, students were retrospectively placed in one of two groups based on if they manipulated the donor, or only handled structures using models, figures, or reviewed electronic sources. Final grades for the laboratory component of the course were listed in two groups: 'C or better' or 'DFW' (students receiving a final grade of 'D', 'F', or students who withdrew from the course). All students who withdrew from either course were categorized as non-manipulators. Scores for the lecture exams or other didactic materials were excluded from this study.

3.1. Student Outcomes on Performance on Laboratory Practical Assessments

3.1.1. Performance on Laboratory Practical Assessments in the Human Anatomy Course

For students enrolled in BIO 201, 90.6% of students who actively manipulated the donor during laboratory sessions received a 'C' or better (58 vs. 6 DFW), and 64.7% of students who did not manipulate the donor earned a DFW (33 vs. 18 C or better) (Table 1). Analysis using a Fisher's exact test determined a strong statistical significance ($p < 0.0001$) that earning a 'C' or better on lab practical assessments is associated with use of the donor in the majors-based human anatomy course

Table 1. Laboratory grade performance in human anatomy courses based on donor use.

		C or Better	DFW	*p*-Value	Relative Risk
BIO 201	Manipulating	58 (50%)	6 (5.17%)		
	Non-manipulating	18 (16.38%)	33 (28.45%)	<0.0001	6.77
BIO 221	Manipulating	34 (55.74%)	2 (3.28%)		
	Non-manipulating	13 (21.31%)	12 (19.67%)	0.0002	8.64
Total	Manipulating	92 (52.27%)	8 (4.55%)		
	Non-manipulating	32 (18.18%)	44 (25%)	<0.0001	7.24

Numerical data for BIO 201 and BIO 221 for the number of students who passed the course with a "C or better", or received a D or F, or withdrew (DFW) from the course, stratified by if they did or did not manipulate the donors. Percentages are for within each course or of the total. *p*-values were calculated using a two-sided Fisher's exact test. Relative risk indicates the risk of DFW for a student who does not manipulate a donor.

3.1.2. Performance on Laboratory Practical Assessments in the Anatomy & Physiology Course

Similar results were seen when analyzing final laboratory grades of students enrolled in BIO 221. Ninety-four percent of students who actively manipulated the donors during laboratory sessions received a 'C' or better (n = 34) versus a non-passing, DFW grade (n = 2). In this course, 52% of 'non-manipulating' students were able to earn a 'C' or better (n = 13) than earning a DFW (n = 12); however, statistically students were more likely to receiving a passing grade for the laboratory assessments with a 'C' or better when actively involved in donor-based learning (p = 0.0002) (Table 1).

3.1.3. Performance on Laboratory Practical Assessments Overall

The student data were also analyzed as a single cohort, and provided additional statistical evidence that students who used the donors were more likely to earn a higher grade for the laboratory component of the course (92 with a 'C' or better vs. 8 DFW) than students who did not use the donors (32 with a 'C' or better vs. 44 DFW; $p < 0.0001$). Our data indicate that a student is 7.24 times more likely to earn a 'DFW' on lab practical assessments in an anatomy-based course when they do not manipulate the donor (Table 1).

4. Discussion

Results of the current study indicate that when undergraduate, pre-professional biology and health sciences majors physically manipulate prosected donor specimens, they perform significantly better on laboratory practical examinations. The impact of this was not limited to a single course, as the BIO 201 and 221 courses had similar outcomes of success when individually comparing students who did and did not manipulate donors. Indeed, the two courses cover different, but overlapping content, and have different student populations enrolled (pre-professional versus health science majors). Outcomes remained comparable when combined and analyzed as well as a single cohort.

Due to the typical class size (maximum enrollment of 24) students used their laboratory time in a varied manner. Students often worked in small groups of 2–4, where they rotated turns as the 'teacher' and reviewed structures for their peers. Students also worked independently, particularly if they (1) needed additional review a set of structures and/or body regions or (2) were reviewing items their grouped peers had already mastered. In either of these cases, the rotation of the student as the 'peer teacher' resulted in all of the 'manipulating' students physically manipulating and/or handling the donor specimens. There was never hesitancy for a 'manipulator' to manipulate the specimens after initially doing so at the beginning of the course. In contrast, 'non-manipulating' students regularly and consistently elected to not physically manipulate the donor. This was as an independent worker, or when working in a peer tutorial arrangement. In frequently, a non-manipulating' student would request for a peer to move an organ or structure to permit better viewing

of deeper items. Presumably this assisted the non-manipulator in gaining additional understanding of the 3D relationships of the target region, but any comparison and/or improvement of the students' spatial ability was not assessed.

Interestingly, there were a larger number of 'non-manipulating' students in the BIO 221 course that earned a DFW grade as compared to the 'manipulating' students. We believe this is attributed to the overall population of students in the course. The BIO 221 course is designed for non-majors and a passing grade of 'D' or above permits students to continue progressing through their program requirements. By comparison, students in the BIO 201 for majors are required to have a 'C' or better to progress to upper-division electives specific to Anatomy content. Indeed, this would include courses such as Histology, Comparative Vertebrate Biology, and Advanced Human Dissection. While this generally provides an explanation for the increased trends of non-manipulators earning a DFW grade, a specific analysis of the student major and their subsequent progression through their academic program would be necessary to quantitatively evaluate the increased occurrence of DFW grades in the BIO 221 courses.

Historically, the BIO 201 and 221 courses have a high DFW rate, which underlies the motivation to enhance student learning and more successful outcomes. Although our emphasis evaluated laboratory performance only, the combined DFW rate for 'manipulating' and 'non-manipulating' students on laboratory assessments is high (42%) for the cohorts analyzed herein (Table 1). By definition, DFW rates for a course overall are inclusive of both lecture and laboratory components; however, we presume that the general rates of DFW grades specific to laboratory performance likely predict the total course performance overall. Indeed, the laboratory assessments analyzed here involved four practical exams worth a total of 50 points each, indicating 200 points stemming from laboratory assessments contributing to the overall total grade for both courses. Additionally, the variability of lecture content covered between the courses was further reason for excluding lecture assessments in our analysis. The biggest content discrepancy is the physiology covered in BIO 221 relevant to each body system included. Because of these reasons, we elected to pursue opportunities for improving student outcomes specific to the laboratory sessions/experience and therefore evaluated the impact of physical manipulation on laboratory assessments only.

4.1. Voluntary Student Withdrawal

A small percentage of students elected to voluntarily withdraw from either course during the time periods analyzed. This contributed to 0.04% of students enrolled for BIO 201 and 10% of students for BIO 221 (Table 1). All of the students were enrolled past the first two weeks of the course, with most enrollments extending to the designated 'last date to withdrawal.' The specific drop date for students withdrawing was not collected for the cohorts analyzed. We elected to include these students (n = 11) in our analyses as our previous university evaluates non-passing outcomes as DFW and we believed this best reflected our lower performing student population as assessed by the institution. While this does not account for the specific reason a student chose to withdraw, the grade outcome is reflective of their participation in lab as they had continued to attend, did not manipulate the donors, and yet decided to drop the course.

4.2. Effectiveness of Educational Methods in Laboratory Anatomy Teaching

Analysis of assessment outcomes specific to dissection, prosection, and other teaching modalities, such as plastic models, has been extensively studied. Studies comparing prosection to dissection have yielded consistently equivocal outcomes [15–18]. Prosections have even been deemed superior to dissection in body regions that are historically more difficult to dissect [18], suggesting that overall size of anatomical structures included in a given body area, and having these structures more readily available for review, positively impacts student outcomes. Additionally, other methods, like plastic anatomy models [19–23] and review of online, instructional anatomy videos [24,25] are effective methods of instruction and result in comparable assessment outcomes. Although these data support the multiple specimens and

teaching modalities as effective for use in anatomy laboratory assessments, none of these reports address the role of physical manipulation by the students specific to laboratory grade outcomes. This is not surprising as many bell-ringer style exams utilized in anatomy lab assessments do not permit students to manipulate the models or structures in question. Consistently, our laboratory assessments did not permit students to manipulate the tagged structures; however, our data do indicate that manipulation during laboratory sessions prior to the exam is critical in positively impacting assessment outcomes.

4.3. Manipulation and Spatial Learning/Ability

The role of physical touch/manipulation in improving assessment outcomes can be indirectly linked to a student's spatial ability. Spatial ability and its role in anatomical education has been long standing [26]. Anatomy comprehension requires understanding the spatial organization and relationships of multiple structures within the human body. Early work with medical students has correlated spatial abilities testing to general anatomy knowledge assessment using practical examination, spatial multiple-choice questions examination, and 3D synthesis from 2D views [27]. Later studies correlating spatial abilities test of 3D synthesis of carpal bone knowledge from 2D views [28–30] have been conducted. These early works have opened the field for studying the relationship between spatial abilities test and anatomy knowledge assessment. Significant relationships have been observed between spatial abilities test and anatomy knowledge assessment using practical examination, three-dimensional synthesis from two-dimensional views, drawing of views, and cross-sections [31–33].

Similarly, the role of physical manipulation of prosected specimens may mimic dissection for early learners. Nwachukwu and colleagues report that the quality of dissection completed by students is associated with higher scores on practice and final practical examinations, supporting the role of working though the layering of organs to gain a better understanding of structural relationships and spatial organization [34]. Considering the role that a complete, dedicated dissection does for the performance of the dissector, a similar principle can be applied to the student who elects to extensively review a prosected donor.

4.4. Study Limitations

We acknowledge the likelihood that numerous reasons may underlie the decision for a student to not physically manipulate the donors, but this was not explored further through a survey analysis addressing student comfortability (or lack thereof). This information could be helpful in understanding the reasoning for a student's willingness to manipulate or not manipulate a donor, as well as provide an opportunity to discuss death and dying within an anatomy course. We elected not to collect demographic information of the students enrolled in the course, and therefore did not characterize students that were grouped as 'manipulators' or 'non-manipulating'. Addressing these parameters, in parallel with examining the role of physical manipulation, would provide more context for the source of improvement on assessment outcomes in students.

5. Conclusions

The desire of all educators is to improve student outcomes and increase knowledge retention in their respective courses. Here, we demonstrate in anatomy-based courses, that when students take part in a more active learning process, i.e., physically manipulating the prosected donors, they perform better on practical assessments. We recommend emphasizing the impact of physical manipulation during in-class activities to enhance the learning environment.

Author Contributions: J.F.D. conceived the initial study idea and B.A.C. conceived the statistical analysis. Data collection of physical manipulation versus visual examination was completed by J.F.D.; B.A.C. completed the statistical analysis. J.F.D. wrote the initial manuscript with support from B.A.C. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement: This project used a nonexperimental design with a convenience sample. Grade data and physical manipulation of the donors were collected with approval from the Institutional Review Board at MSSU (protocol #985984-1); no participation incentives were offered. Graded laboratory data/content were calculated and compared across different sections. To protect student anonymity, students were assigned a numerical identifier not related to their student ID assigned by the University; these values were assigned by a University employee that was not a course instructor. All grade and contact data were evaluated using these non-identifying IDs. Statistical analyses were performed by B. A. Creamer, who was not a course instructor for any of the sections.

Informed Consent Statement: Informed consent was waived due to the research involving no more than minimal risk to the subjects and the waiving of informed consent would not adversely affect the rights and welfares of the subjects as the study did not collect any identifiable nor demographic information.

Data Availability Statement: Not applicable.

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References

1. Daempfle, P.A. An Analysis of the High Attrition Rates among First Year College Science, Math, and Engineering Majors. *J. Coll. Stud. Retent. Res. Theory Pract.* **2003**, *5*, 37–52. [CrossRef]
2. Hopper, M.K. Assessment and comparison of student engagement in a variety of physiology courses. *Adv. Physiol. Educ.* **2016**, *40*, 70–78. [CrossRef]
3. Schutte, A.F. Who is repeating anatomy? Trends in an undergraduate anatomy course. *Anat. Sci. Educ.* **2016**, *9*, 171–178. [CrossRef] [PubMed]
4. Attardi, S.M.; Rogers, K.A. Design and implementation of an online systemic human anatomy course with laboratory. *Anat. Sci. Educ.* **2015**, *8*, 53–62. [CrossRef]
5. Attardi, S.M.; Choi, S.; Barnett, J.; Rogers, K.A. Mixed methods student evaluation of an online systemic human anatomy course with laboratory. *Anat. Sci. Educ.* **2016**, *9*, 272–285. [CrossRef]
6. Attardi, S.M.; Barbeau, M.L.; Rogers, K.A. Improving Online Interactions: Lessons from an Online Anatomy Course with a Laboratory for Undergraduate Students. *Anat. Sci. Educ.* **2018**, *11*, 592–604. [CrossRef] [PubMed]
7. Wisenden, P.A.; Budke, K.J.; Klemetson, C.J.; Kurtti, T.R.; Patel, C.M.; Schwantz, T.L.; Wisenden, B.D. Emotional response of undergraduates to cadaver dissection. *Clin. Anat.* **2018**, *31*, 224–230. [CrossRef] [PubMed]
8. Kang, S.H.; Shin, J.S.; Hwang, Y.I. The use of specially designed tasks to enhance student interest in the cadaver dissection laboratory. *Anat. Sci. Educ.* **2012**, *5*, 76–82. [CrossRef] [PubMed]
9. Hajj, I.; Dany, M.; Forbes, W.; Barremkala, M.; Thompson, B.J.; Jurjus, A. Perceptions of human cadaver dissection by medical students: A highly valued experience. *Ital. J. Anat. Embryol.* **2015**, *120*, 162–171. [PubMed]
10. Leboulanger, N. First cadaver dissection: Stress, preparation, and emotional experience. *Eur. Ann. Otorhinolaryngol. Head Neck Dis.* **2011**, *128*, 175–183. [CrossRef] [PubMed]
11. Greene, S.J.; Rosen, L. Tracking medical student emotionality in relation to whole body dissection and donation. *Clin. Anat.* **2021**, *34*, 128–142. [CrossRef]
12. Romo-Barrientos, C.; Criado-Álvarez, J.J.; González-González, J.; Ubeda-Bañon, I.; Flores-Cuadrado, A.; Saiz-Sánchez, D.; Viñuela, A.; Martin-Conty, J.L.; Simón, T.; Martinez-Marcos, A.; et al. Anxiety levels among health sciences students during their first visit to the dissection room. *BMC Med. Educ.* **2020**, *20*, 109. [CrossRef]
13. Romo-Barrientos, C.; Criado-Álvarez, J.J.; Martínez-Lorca, A.; Viñuela, A.; Martin-Conty, J.L.; Saiz-Sanchez, D.; Flores-Cuadrado, A.; Ubeda-Bañon, I.; Rodriguez-Martín, B.; Martinez-Marcos, A.; et al. Anxiety among nursing students during their first human prosection. *Nurse Educ. Today* **2020**, *85*, 104269. [CrossRef]
14. Winston, H. A medical student-cadaver relationship. *Virtual Mentor* **2012**, *14*, 419–421.
15. Yeager, V.L. Learning gross anatomy: Dissection and prosection. *Clin. Anat.* **1996**, *9*, 57–59. [CrossRef]
16. Topp, K.S. Prosection vs. dissection, the debate continues: Rebuttal to Granger. *Anat. Rec. B New Anat.* **2004**, *281*, 12–14. [CrossRef]

17. Winkelmann, A.; Hendrix, S.; Kiessling, C. What do students actually do during a dissection course? First steps towards understanding a complex learning experience. *Acad. Med.* **2007**, *82*, 989–995. [CrossRef]
18. Williams, S.R.; Thompson, K.L.; Notebaert, A.J.; Sinning, A.R. Prosection or Dissection: Which is Best for Teaching the Anatomy of the Hand and Foot? *Anat. Sci. Educ.* **2019**, *12*, 173–180. [CrossRef]
19. Wright, S.J. Student perceptions of an upper-level, undergraduate human anatomy laboratory course without cadavers. *Anat. Sci. Educ.* **2012**, *5*, 146–157. [CrossRef]
20. Khot, Z.; Quinlan, K.; Norman, G.R.; Wainman, B. The relative effectiveness of computer-based and traditional resources for education in anatomy. *Anat. Sci. Educ.* **2013**, *6*, 211–215. [CrossRef]
21. Lombardi, S.A.; Hicks, R.E.; Thompson, K.V.; Marbach-Ad, G. Are all hands-on activities equally effective? Effect of using plastic models, organ dissections, and virtual dissections on student learning and perceptions. *Adv. Physiol. Educ.* **2014**, *38*, 80–86. [CrossRef] [PubMed]
22. Yammine, K.; Violato, C. The effectiveness of physical models in teaching anatomy: A meta-analysis of comparative studies. *Adv. Health Sci. Educ. Theory Pract.* **2016**, *21*, 883–895. [CrossRef] [PubMed]
23. Mitrousias, V.; Karachalios, T.S.; Varitimidis, S.E.; Natsis, K.; Arvanitis, D.L.; Zibis, A.H. Anatomy Learning from Prosected Cadaveric Specimens Versus Plastic Models: A Comparative Study of Upper Limb Anatomy. *Anat. Sci. Educ.* **2020**, *13*, 436–444. [CrossRef]
24. Langfield, T.; Colthorpe, K.; Ainscough, L. Online instructional anatomy videos: Student usage, self-efficacy, and performance in upper limb regional anatomy assessment. *Anat. Sci. Educ.* **2018**, *11*, 461–470. [CrossRef]
25. Greene, S.J. The Use of Anatomical Dissection Videos in Medical Education. *Anat. Sci. Educ.* **2020**, *13*, 48–58. [CrossRef]
26. Vorstenbosch, M.A.; Klaassen, T.P.; Donders, A.R.; Kooloos, J.G.; Bolhuis, S.M.; Laan, R.F. Learning anatomy enhances spatial ability. *Anat. Sci. Educ.* **2013**, *6*, 257–262. [CrossRef] [PubMed]
27. Rochford, K. Spatial learning disabilities and underachievement among university anatomy students. *Med. Educ.* **1985**, *19*, 13–26. [CrossRef]
28. Garg, A.; Norman, G.R.; Spero, L.; Maheshwari, P. Do virtual computer models hinder anatomy learning? *Acad. Med.* **1999**, *74* (Suppl. S10), S87–S89. [CrossRef]
29. Garg, A.X.; Norman, G.; Sperotable, L. How medical students learn spatial anatomy. *Lancet* **2001**, *357*, 363–364. [CrossRef]
30. Garg, A.X.; Norman, G.R.; Eva, K.W.; Spero, L.; Sharan, S. Is there any real virtue of virtual reality?: The minor role of multiple orientations in learning anatomy from computers. *Acad. Med.* **2002**, *77* (Suppl. S10), S97–S99. [CrossRef]
31. Langlois, J.; Bellemare, C.; Toulouse, J.; Wells, G.A. Spatial abilities and technical skills performance in health care: A systematic review. *Med. Educ.* **2015**, *49*, 1065–1085. [CrossRef]
32. Langlois, J.; Bellemare, C.; Toulouse, J.; Wells, G.A. Spatial abilities and anatomy knowledge assessment: A systematic review. *Anat. Sci. Educ.* **2017**, *10*, 235–241. [CrossRef] [PubMed]
33. Langlois, J.; Bellemare, C.; Toulouse, J.; Wells, G.A. Spatial Abilities Training in Anatomy Education: A Systematic Review. *Anat. Sci. Educ.* **2020**, *13*, 71–79. [CrossRef] [PubMed]
34. Nwachukwu, C.; Lachman, N.; Pawlina, W. Evaluating dissection in the gross anatomy course: Correlation between quality of laboratory dissection and students outcomes. *Anat. Sci. Educ.* **2015**, *8*, 45–52. [CrossRef] [PubMed]